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NEW TECHNIQUE FOR MAKING THIN HORIZONTAL INJECTION FOUNDATIONS --ETC(U)
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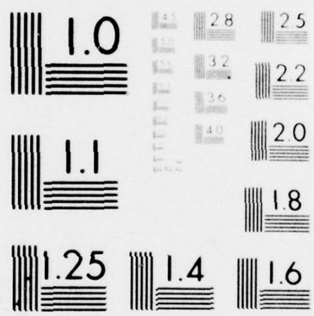

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Draft Translation 559
December 1976

NEW TECHNIQUE FOR MAKING THIN HORIZONTAL INJECTION FOUNDATIONS

J.H. Buttner

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COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Draft Translation 559	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) NEW TECHNIQUE FOR MAKING THIN HORIZONTAL INJECTION FOUNDATIONS		5. TYPE OF REPORT & PERIOD COVERED Translation
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J.H. Buttner		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Cold Regions Research and Engineering Laboratory Hanover, New Hampshire		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE December 1976
		13. NUMBER OF PAGES 10
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) FOUNDATIONS (STRUCTURES) INJECTION		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report discusses injection foundations. These foundations reduce permeability and prevent the underground water level drop outside a construction pit. It also cuts down the possible salt charge in a main canal.		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(14) CRREL-TL-559

DRAFT TRANSLATION 559

(6)

~~ENGLISH TITLE~~: NEW TECHNIQUE FOR MAKING THIN HORIZONTAL INJECTION FOUNDATIONS

~~FORIGN TITLE~~: (NEUE TECHNIK ZUR HERSTELLUNG DUNNER HORIZONTALER INJEKTIONSSOHLEN);

~~AUTHOR: J.H. Buttner~~ (West Germany)

(21) Trans. of

[redacted] Die Bautechnik [redacted] V51 [redacted] N2 [redacted] p62-65

1974.

ACCESSION for	
NTIS	White Section ✓
DDC	Buff Section ☐
UNANNOUNCED	☐
JUSTIFICATION	
BY	
DISTRIBUTION/AVAILABILITY CODES	
Dist.	AVAIL. and/or SPECIAL
A	

Translated by Office of the Assistant Chief of Staff for Intelligence for U.S. Army Cold Regions Research and Engineering Laboratory, 1976, 10P.

(10) Joachim H. Buettner

(11) Dec 76

(12) 13p.

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NEW TECHNIQUE FOR MAKING THIN HORIZONTAL INJECTION FOUNDATIONS

By Engineer Joachim H. Büttner, Nederhorst Grundtechnik Gouda, The Netherlands

1. Introduction

In recent years we can detect a definite tendency toward ever larger and thus frequently also deeper and deeper structures. The excavation of large-area and deep construction pits, primarily in population concentration areas, creates difficult requirements for planners and for the underground construction companies that do the job.

One of the problems encountered in this connection deals with the mastery of underground water subsidence. Here, the installation and maintenance of the ground water subsidence systems mostly plays only a subordinate role. The emphasis however is on phenomena deriving from the frequently widespread underground water level drop. Underground water level drops of up to 10 m (where water volumes of 1,500-2,000 m^3/hr are by no means rare) can cause serious settlement damage to structures in the immediate and broader surroundings. In areas near the coast, we also have the pumping of brackish, gradually more salt-containing underground water which, because of environmental protection regulations, must not be dumped into surface waters (Figure 1).

FIGURE NOT REPRODUCIBLE

Figure 1. Partially excavated construction pit, ABN [abbreviation unknown] Computer Center, Amstelveen (Aerophoto-Schiphol).

To the extent that there is no natural, adequately thick layer, such as clay or marl, available at suitable depths, such a sealing layer can today be made artificially by means of injections, using present-day equipment.

These injection foundations--mostly on a base of silicate gels [silicagel]--reduce the permeability, for example, of a medium sand, down to 1/1,000 of the original value. Because of this it is possible either entirely to prevent the underground water level drop outside the construction pit or to keep it within acceptable limits. At the same time, we can considerably cut down the possible salt charge in a main canal.

2. Method for Making Horizontal Injection Foundations

From past records we have several examples of construction projects where horizontal sealing layers were used successfully for the purpose of reducing the developing water volume in the construction pit.

2.1. Methods Known So Far

In these known practical application examples, methods for vertical injection were simply used also for horizontal injection layers. Sleeve pipes were inserted with the help of bore holes and they were surrounded by a bracing fluid mud.

Where soil conditions permitted, sleeve pipes were also jet-rammed in, whereby the penetration of the injection material upward was prevented likewise with the help of the fluid mud. In simple cases it is also enough to ram the injection pipes in.

2.2. Disadvantages of Known Methods

If we use the traditional methods for vertical injection layers also for horizontal sealing foundations, then we get some decisive disadvantages.

First of all, because of the relatively expensive drilling method, we will try to select the drill hole interval as large as can be justified in terms of injection technique. This means that the sealing floor [foundation] on the average will be at least as thick as the drill hole interval is wide. Depending upon the soil permeability, 1.5-3.0 m would be generally customary here. The practically required injection quantity then comes to about as much as 1,200 liters per injection point. The dosing of the reagent for the silicate mixture must then be coordinated in terms of the pumping time required here. If we want to attain a homogeneous permeation of the soil layer with injection material, then the "realization time" [moment of tilting] may come only after the completion of injection.

Because, as we know, the quality of silicate gels depends on the quantity of available reagents, we thus get a qualitatively inferior injection body.

On the other hand, the soil should never be considered homogeneous; we therefore always get certain irregularities in the theoretical spherical shape of the injection body. We can easily see that a large interval between the injection points involves a greater risk, apart from the measurement

inaccuracies and the vertical deviations of the bore holes.

2.3. Vibrator Technique--A New Possibility

With the help of vibrator techniques it is now possible to work economically with a small interval between injection points, perhaps 1.0 m. Here we get thinner but qualitatively better sealing foundations.

The new method, developed by Nederhorst Grundtechnik, consists in the following: with the help of a vibrator, several lost injection elements are simultaneously brought to the required depth and through those elements, the injection material can be forced independently of the insertion process.

The quantity of injection mass to be pressed in comes to about 330 liters per injection point, as a function of the pore volume, and the job can be done in about 30 minutes. In this way we can achieve a relatively short relaxation time and we can thus get a qualitatively better silicate gel by means of heavier dosing of reagents.

3. Insertion of Lost Injection Elements With Help of Vibrator

With the help of the vibrator technique, several auxiliary stakes can be vibrated in, down to a depth of more than 20 m, in certain soil conditions, and can then be drawn.

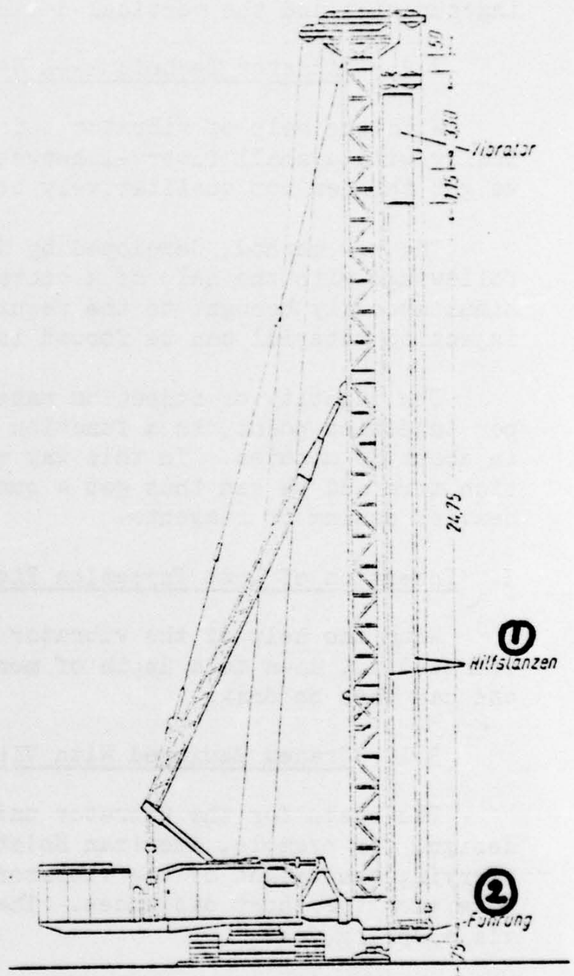
3.1. Cranes Equipped With Vibrators (Figure 2)

The basis for the vibrator units is a medium-heavy crane of standard design, for example, American Hoist, Model 5299, which is capable of reliably carrying the weight of the vibrator as well as the auxiliary stakes and to move them for short distances. The vibrator is carried loose on the tower via a spring yoke.

The auxiliary stakes are connected with the vibrator in a force-locking manner via a rigid console. The drive unit of the vibrator's electric motors can be used as counterweight. In keeping with the anticipated penetration as it stands, one can use various vibrators with changing amplitude and frequency.

Figure 2. Vibrator Unit.

Legend: 1--Auxiliary Stakes;
2--Control.



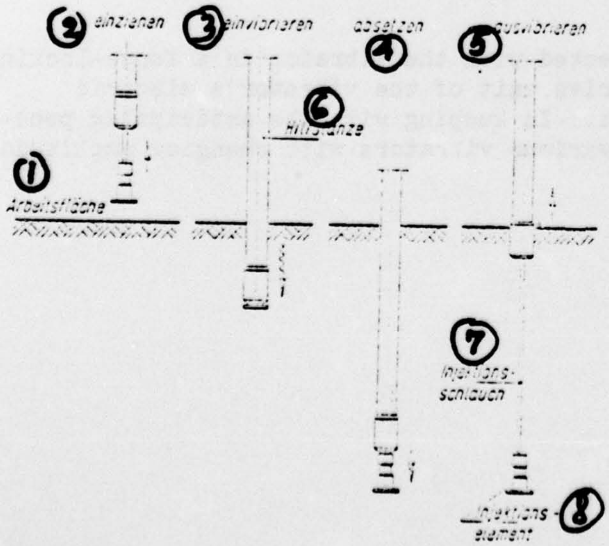


Figure 3. Insertion P Phases for Lost [Dead] Injection Elements.

Legend: 1--Working Surface;
2--Pull In;
3--Vibrate In;
4--Put Down;
5--Vibrate Out;
6--Auxiliary Stake;
7--Injection Hose;
8--Injection Element.

3.2. Auxiliary Stakes

The auxiliary stakes are used to vibrate the dead injection element into the desired depth. For effective in-vibration, the profile [section piece] should be as rigid as possible, on the one hand; on the other hand, a large profile increases the friction forces.

In order to put the dead injection elements down at the required depth, a second pipe is arranged in the auxiliary stake. With the help of this inside pipe, we can transmit a pressure force upon the injection element via a hydraulic press mounted in the console.

3.3. The Dead Injection Element

The injection element is nothing more than a valve which prevents the penetration of soil particles during the "put-down" and which later on facilitates the pressing of injection material. At the same time it works as dead "ramhead" for the auxiliary stakes. Because of this twin function, it consists of massive steel with inside bore and openings to the outside which are covered with a rubber hose. It is furthermore provided with a simple connection possibility for the injection hose leading to the terrain surface.

3.4. Insertion of Injection Element (Figure 3)

The dead injection elements are inserted in four phases:

Pull in--vibrate in--put down--vibrate out.

The injection elements are connected to a plastic hose. That hose is first of all connected with a steel wire with whose help the elements are drawn into the auxiliary stake, until the element closes the auxiliary stakes off at the bottom.

Afterward, the auxiliary stakes are vibrated to the desired depth. By activating the hydraulic presses, the injection elements are put down on the inside pipe due to pressure. Then comes the out-vibration of the auxiliary stakes. By means of protracted vibration over the injection element, we can achieve a certain consolidation of the soil which prevents a subsequent breakout of the injection material upward. After the auxiliary stake has been extracted, the connection between the injection hose and the steel wire can be severed and the injection elements are ready for the pressing stage.

4. Pressing Through Dead Injection Elements

After the installation of the injection elements--which are connected with the terrain surface by means of a plastic hose--the pressing phase can be started. The mixture of the injection material, which is automatically prepared in the injection center, is placed into the storage tank of the

injection pump. The injection hose, running from the injection pump, is coupled with the plastic hose of the element and the pressing phase can then take place automatically.

Because the injection pump has a fixed pump output within a certain pressure range (for example, 10 liters per minute), it suffices, for control purposes, to observe the development of the pressure phase during the actual pressing and the course of the pressure phase is automatically recorded by means of a pressure recorder. The initial pressure used in opening the valves is definitely greater than the actual pressing pressure. The plastic hoses must be properly dimensioned for this. In general, that pressure is not greater than 20-30 kp/cm^2, which this particular plastic material permits quite readily. The actual injection pressure, depending upon the soil structure and the viscosity of the pressing material, is between 7 and 15 kp/cm^2, measured at the pump output.

5. Practical Examples

Several sealing foundations were made successfully according to this method in recent years, whereby the surfaces of the construction pit came to 7,000 m^2 while the depths of the injection floors were 23 m below the working level.

In the following we will briefly describe some projects and we will give the most important data.

5.1 5.1. Schiphol Tunnel, Phase 1 (Figure 4)

A tunnel had to be built under a new runway as part of a planned rail link between Amsterdam and Schiphol Air Terminal.

The building lot was 520 m long, featuring the louvered slide [wall] construction method, and was, for trial purposes, built for a distance of 190 m with a permanent sealing foundation [floor].

Data: Injection depth 16.00 m below G. O. K. [upper edge of terrain surface?]; area of sealing foundation approximately 2,000 m^2; six injection elements installed simultaneously; number of injection points approximately 2,850.

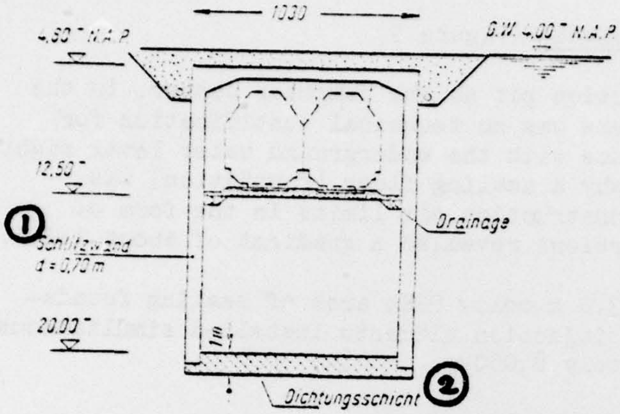


Figure 4. Cross Section, Schiphol Tunnel, Phase 1

Legend: 1--Louvered Wall; 2--Sealing Layer; G. W.--Underground Water Level; N. A. P. [abbreviation unknown].

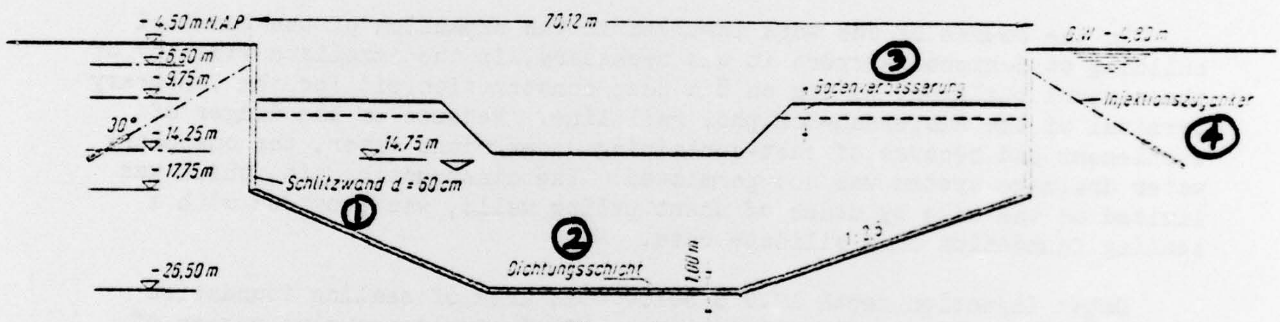


Figure 5. Cross Section, Construction Pit, Computer Center ABN, Amstelveen

Legend: 1--Louvered Wall; 2--Sealing Layer; 3--Soil Improvement; 4--Injection Traction Anchor.

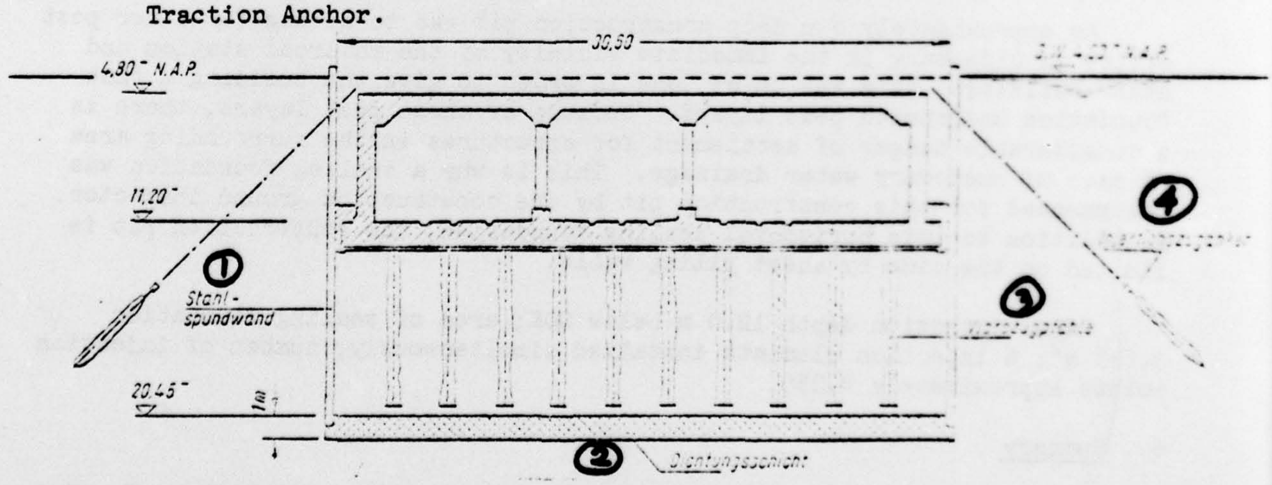


Figure 6. Cross Section, Construction Pit and Schiphol Tunnel, Phase II.

Legend: 1--Steel Sheet Piling; 2--Sealing Layer; 3--Vibration Traction Post; 4--Injection Traction Anchor.

5.2. ABN Computer Center, Amstelveen (Figure 5)

For the up to 10 m deep construction pit at the computer center, in the midst of a heavily built-up area, there was no technical justification for a standard underground water subsidence with the underground water level right below the terrain surface. This is why a sealing floor [foundation] was provided next to the perpendicular construction pit limits in the form of louvered walls; the floor in some portions revealed a gradient of about 1:2.5.

Data: Maximum injection depth 23.0 m below GOK; area of sealing foundation approximately 7,100 m^2; 8 and 6 injection elements installed simultaneously; number of injection points approximately 8,000.

5.3. Schiphol Tunnel Phase 2 (Figure 6)

In the course of the work involved in the expansion of the terminal building at Schiphol Airport it was necessary, in the immediate vicinity of the airport building, to dig an 8 m deep construction pit for the temporary terminal of the Amsterdam-Schiphol rail line. Because of the danger of settlement and because of salt-containing underground water, the customary water drainage system was not permitted. The construction pit, which was limited on the side by means of sheet piling walls, was provided with a sealing foundation on a silicate base.

Data: Injection depth 17.0 m below GOK; area of sealing foundation 3,010 m^2; 6 and 4 injection elements installed simultaneously; number of injection points approximately 3,500.

5.4. Oldenburg Post Office

An approximately 6-m deep construction pit was to be dug for a new post office in Oldenburg in the immediate vicinity of the railroad station and other buildings; this was to be done in order to give the building a flat foundation underneath peat layers. Because of these peat layers, there is a considerable danger of settlement for structures in the surrounding area in case of customary water drainage. This is why a sealing foundation was recommended for this construction pit by the construction ground inspector. In addition to this horizontal sealing foundation, the construction pit is limited on the side by sheet piling walls.

Data: Injection depth 12.0 m below GOK; area of sealing foundation 3,745 m^2; 6 injection elements installed simultaneously; number of injection points approximately 4,350.

6. Summary

Large-surface and deep construction pits, provided with sealing foundations, are becoming increasingly important for economic, technical, and environmental protection reasons.

In addition to the conventional technique used in making sealing foundations--that is to say, the drilling method--the use of the vibrator technique offers new possibilities. This method makes it possible, with greater precision, to make thinner and qualitatively better injection foundations on a silicate base with operation limited in terms of time or with permanent operation.

The average permeability values of an approximately 1.0 m thick injection floor [foundation] is on the order of magnitude of $1.0 \cdot 10^{-6}$ to $5.0 \cdot 10^{-5}$ and they thus reduce the developing water volumes, for example, in an average sand layer to 1/1,000 to 1/500 of the original water volume. This prevents settlement damage in the surrounding areas; the remaining water drainage in the construction pit becomes simpler, for example, in the form of a surface drainage system.

By installing up to eight dead injection elements in one work operation lasting just a few minutes and through the consistent separation of the insertion and the pressing process, one can obtain economical advantages compared to the hitherto known drilling technique.

This technique, developed by Nederhorst Grundtechnik, is economical not only in comparison to the presently known methods but also in cases where followup damage resulting from underground water subsidence can be avoided with the help of absorption well systems.

Table 1. Important Data on Construction Pit Sealing Projects Carried Out.

1 Ausführungsperiode	2 Bauprojekte	3 abgedichtete Fläche (m^2)	4 Tiefe Injektionssohle unter G.O.K. (m)	5 max. hydraul. Gefälle i (1)	6 max. geförderte Restwassermenge (m^3/h)	7 Durchlässigkeitsbeiwerte: 8 natürlicher Boden (cm/s)	9 injizierter Boden (cm/s)
1966	Schipholtunnel Phase 1	1950 (7 Abschnitte) 14	16,00	8,50	1,0—6,0	$2{,}5 \cdot 10^{-2}$	$1{,}0 \cdot 10^{-4}$ bis 15 $1{,}7 \cdot 10^{-4}$
Aug./Sept. 1967	Regenwasser-sammelbecken, Unterführung, Amstelveen 11	290	15,80	7,80	0,4	$3{,}25 \cdot 10^{-2}$	$5{,}0 \cdot 10^{-4}$
Apr./Nov. 1971	Computerzentrum ABN Amstelveen 12	7325 (2 Abschnitte) 14	16,70—22,70	7,95—10,45	200[1])	$1{,}5 \cdot 10^{-2}$	$1{,}0 \cdot 10^{-5}$ [4])
März/Aug. 1972 10	Schipholtunnel Phase 2	3010 (2 Abschnitte) 14	17,35	8,50	35[2])	$2{,}85 \cdot 10^{-2}$	$3{,}3 \cdot 10^{-5}$ [2])
Sept./Okt. 1972	Postgebäude Oldenburg in Oldenburg 13	3745	12,00	5,50	—[3])	$1{,}8 \cdot 10^{-2}$	— [3])
July/Nov. 1973	Schipholtunnel Phase 3	1600	20,60	8,65	—[4])	$3{,}0 \cdot 10^{-2}$	— [4])

Legend: 1--Construction Period; 2--Construction Project; 3--Sealed Surface; 4--Depth of Injection Foundation Below GOK; 5--Maximum Hydraulic Gradient; 6--Maximum Residual Water Volume Pumped; 7--Permeability Coefficient; 8--Natural Soil; 9--Injected Soil; 10--March; 11--Rainwater Collecting Basin, Under Path; 12--Computer Center; 13--Post Office Building; 14--Phases; 15--to.

(1) Including about 60 m^3/hr for a leak that was not plugged up;
(2) Including an unknown water volume for leaky sheet piling wall lock;
(3) Not yet excavated because of delays; (4) In progress.